



Airplane Design Perspectives of Engine Controls Technology Needs



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787 and 747-8F

Certification and Delivery in 2011

BCA | Propulsion Controls Engineering



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Topics:

- **Propulsion System Malfunction & Inappropriate Crew Response (PSM+ICR)**
- **Engine Performance for Emergency Conditions**

Propulsion System Malfunction & Inappropriate Crew Response (PSM+ICR)

FAA funded research

Phase 1 study launched after AIA/AECMA review of 80+ a/c accidents/incidents with subsequent pilot action not appropriate to the condition

Phase 1 determined that for some of the events (non > V1 RTO) crew alerting of engine malfunctions could be beneficial

Alert: indication in the cockpit specifically for pilot awareness or action

What are the right alerts?

How/when should they be displayed?

Phase 2: What alerts are appropriate for sustained thrust anomalies

Study required collaboration of Propulsion, Flights Deck, Human Factors and Pilots.

Propulsion: inputs from Boeing, GE, PW (controls, operability, thermo/mechanical)

Flight Deck: Interfacing between engineering, human factors and pilots

Human Factors: Applying human capabilities and limitations to the design of technical products.

Pilots: Knowing what they need to fly the airplane

Important factors for pilot alerting of thrust anomalies

Provide appropriate type of awareness

Provide specific guidance

Timing

Reliability

Provide alert for a sustained condition – not for a transient condition

- Don't want a “worry” light**

e.g. no display for a recoverable surge

Phase 2 identified nine types of sustained thrust anomalies

- **Flameout**
- **Surge/Non-recoverable stall**
- **Continuous/Multiple surging**
- **Thrust high or low (primary thrust set parameter sensor shift)**
- **Thrust low (thrust shortfall)**
- **Thrust high (overthrust)**
- **Engine slow to accelerate**
- **Thrust failed low (damage) – deferred to phase 3**
- **Thrust oscillations – not a PSM+ICR contributor**

Phase 2 identified suite of four alerts for sustained thrust anomalies

■ Engine subidle

- Affects electrical loads
- Requires pilot to shutdown engine or attempt a restart

■ Engine thrust anomaly requiring an EEC Mode Change

■ Other thrust anomaly (thrust high, thrust low - but not subidle)

- Pilot awareness of performance change and affect on airplane handling

■ Engine continuously surging

- Requires pilot to retard the thrust lever to clear the surging
- Technology need for reliable/timely alert

Phase 3: Alerting for a damaged engine that continues to operate

What will the pilot do with the information?

Pilots want to be told what they need to do to operate the airplane

Pilots do not want a “worry light”

Pilots want an alert that provides specific instruction – eg diversion required

Pilots want to know about engine damage only if it affects the current flight

They don't want to know if the action is for maintenance after landing

Phase 3: Alerting for a damaged engine that continues to operate

Technology needs:

How is engine damage detected with high reliability?

How can the detection reliably determine how much longer an engine will continue to provide rated thrust?

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NASA studies have identified benefits for:

Increased engine thrust during emergency situations

Increased accel times during emergency situations

Although both have performance benefits, airplane design and certification considerations will affect how these concepts can be implemented

Increased Engine Thrust During Emergency Operation

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Engine/Airplane Design Considerations for Increased Engine Thrust:

Operation above max rated thrust would require consideration of engine stall and EGT exceedances

Stall mapping and certification based on max rated thrust

EGT margins are monitored by the airlines, based on max rated thrust

Engine nacelle design based on max rated thrust (weight optimization)

Thrust higher than rated thrust could result in inlet separation and thrust loss

Part 25 certification of a system that relies on increased rated thrust for an emergency, would require insuring that the thrust is available

Increased Engine Thrust During Emergency Operation

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Airplane Design Considerations (cont):

New airplane programs focus on cost and weight savings

Training is a significant airline cost. An emergency maneuver that requires a unique operation increases training costs

The rudder is sized for engine-out operation – eg the thrust difference between an engine at max rated thrust and a windmilling engine.

An “emergency use only thrust” can only be used for single engine operation with a rudder sized for the higher asymmetric thrust.

Increased Accel Times During Emergency Situations

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Airplane Design Considerations of Engine Accel Times:

Pre-FADEC controls resulted in un-even accels

New engine vs deteriorated engine

Pilots did not like the resultant yaw

FADEC engine controls have been designed to standardize accel times

Airplane design requirement

All engines now accel the same as the most deteriorated engine

Increased Accel Times During Emergency Situations

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Airplane Design Considerations of Engine Accel Times:

To improve efficiency (SFC), the bypass ratios of commercial engines keep increasing

Higher bypass ratios means larger fans

Larger fans means slower accel times

In recent new airplane programs, meeting accel time design objectives has been challenging.

Increased Accel Times During Emergency Situations

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Current engine accel times are determined from the stall margins of a deteriorated engine.

Some engines have stall margin (new engines)

Some do not (deteriorated engines)

Part 25 certification of a system that relies on increased engine accel times for an emergency, would require insuring that the accel rate is available for all engines (new or deteriorated)

Technology need: the means to achieve faster acceleration for deteriorated high bypass engines

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Questions?



